Infants move to music, but coordinated rhythm takes a year to emerge

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The human capacity to perceive music and respond to it with movement is a universal phenomenon, yet the developmental trajectory of this intricate auditory-motor coupling in early infancy remains largely uncharacterised. While the neural encoding of music has seen extensive study, the precise timeline for when and how infants spontaneously begin to move in response to musical stimuli has been less explored. A study published in eLife investigated the simultaneous development of neural and motor responses to music during the first postnatal year.1

KEY TAKEAWAYS

- The Pivot: Auditory encoding of music is present from 3 months, but structured movement to music develops much later, by 12 months.
- The Data: Infants at 12 months demonstrated more complex structured movement patterns to music compared to younger age groups.1
- The Action: Clinicians should recognise the developmental lag between auditory processing and motor expression in infants' music responses.

Humans across cultures share an innate ability to recognise music and respond to it through movement. This fundamental aspect of human experience, however, does not simply appear fully formed. Understanding its developmental origins requires a detailed look at how the infant brain processes musical input and translates it into motor output. The interplay between auditory perception and motor action in early life offers critical insights into neurodevelopmental pathways.1 Nguyen and colleagues conducted a cross-sectional study involving 79 infants, stratified into three age groups: 3 months (N=27), 6 months (N=26), and 12 months (N=26). The researchers simultaneously recorded neural activity using electroencephalography (EEG) and body kinematics via markerless pose estimation. This dual approach allowed for a comprehensive assessment of both sensory encoding and spontaneous motor responses.1

Designing the musical stimulus

The research team carefully selected musical stimuli to probe specific aspects of auditory processing and motor response. Infants listened to refrains of children's music, which served as the primary musical condition. To isolate the effects of musical structure, the researchers also presented shuffled versions of the same songs, which maintained the spectral content but disrupted temporal and melodic organisation.1

They also included high-pitched and low-pitched versions of the songs. These variations allowed the investigators to examine the influence of pitch on both neural and motor responses, providing a more granular understanding of how

infants process different acoustic features of music. The use of familiar children's music aimed to maximise engagement and ecological validity for the infant participants.1

Neural responses to music emerge early

Neural data, collected through EEG, revealed that infants across all age groups exhibited enhanced auditory responses to music compared to shuffled music. This finding indicates that the auditory encoding of music, specifically the ability to differentiate organised musical sounds from disorganised ones, emerges early in development. The brain's capacity to process musical structure appears to be a foundational skill present even in very young infants.1

This early neural differentiation suggests that the auditory system is already tuned to detect and prefer structured musical patterns over random acoustic sequences by 3 months of age. The consistency of this response across the age groups (3, 6, and 12 months) underscores the robust and early development of basic musical perception. It implies that the neural machinery for music processing is operational well before complex motor responses become evident.1

But the study also found a nuanced effect related to pitch. Enhanced auditory responses to high versus low pitch were only evident at 6 months of age. This suggests a transient sensitivity or a specific developmental window during which pitch discrimination becomes particularly salient for neural processing. It raises questions about why this heightened sensitivity was not observed at 3 or 12 months, potentially indicating a reorganisation or integration of pitch processing into broader auditory schemes as development progresses.1

The gradual development of movement

Movement data, captured through markerless pose estimation, told a different story regarding the development of spontaneous movements to music. While coarse auditory-motor coupling was present at all ages, more complex structured movement patterns emerged in response to music only by 12 months. This indicates a significant developmental lag between the brain's ability to perceive music and the body's ability to respond to it with organised, intentional movement.1

Younger infants, at 3 and 6 months, showed some general movement in response to music, but these movements lacked the structured, patterned quality observed in 12-month-olds. The transition to more complex movements by 12 months suggests a maturation of motor control, integration of sensory information, and potentially cognitive understanding of musical rhythm and tempo. This aligns with broader developmental milestones where infants gain greater control over their bodies and begin to engage in more coordinated actions.1

Notably, no age group demonstrated evidence of coordinated movements to music. This is a critical distinction. While 12-month-olds exhibited more structured movements, these were not necessarily synchronised with the music's beat or rhythm. This suggests that true rhythmic entrainment, the ability to move in time with music, is a more advanced skill that develops beyond the first postnatal year. The study differentiates between spontaneous, structured movement and precise, coordinated rhythmic movement.1

Pitch and movement: a consistent link

Interestingly, infants' movements were better predicted by high-pitched compared to low-pitched music at all ages. This finding contrasts with the neural data, where enhanced auditory responses to high versus low pitch were only evident at 6 months. The consistent influence of high-pitched music on movement across all ages suggests a fundamental preference or responsiveness to higher frequencies in the motor system, independent of the specific neural processing patterns

observed at different ages.1

This consistent motor response to high-pitched music could be attributed to several factors. High-pitched sounds often carry more salience or urgency for infants, potentially eliciting a stronger motor response. It might also relate to the acoustic properties of children's music, which frequently features higher pitches. The enduring link between high pitch and movement across the first year highlights a persistent characteristic of infant auditory-motor integration.1

Where the data falls short

The cross-sectional design is an obvious caveat. While it provides snapshots of development at different ages, it cannot track individual developmental trajectories. A longitudinal study would offer a more robust understanding of how neural and motor responses to music evolve within the same infants over time. This would help to clarify the dynamic interplay between sensory and motor development.1

The study also focused on spontaneous movements, not explicitly on rhythmic entrainment. The absence of coordinated movements to music across all age groups, while a clear finding, means the study does not fully address when infants begin to move in time with music. Future research could employ more specific paradigms to elicit and measure rhythmic coordination. The definition of 'structured movement patterns' could also benefit from further refinement and objective quantification.1

The use of children's music, while ecologically valid, introduces a potential confound. Infants may have prior exposure to these specific songs, which could influence their responses. Future studies might consider using novel musical stimuli to control for familiarity effects. Furthermore, the study did not explore the impact of visual cues or social interaction, which are known to influence infant development and engagement with music.1

The sample size for each age group (N=26 or N=27) is sufficient for detecting broad trends, but it may limit the power to identify more subtle differences or subgroup effects. The generalizability of these findings to infants from diverse cultural backgrounds also warrants further investigation. Music perception and movement responses can be influenced by cultural exposure, and this study primarily involved infants from a specific cultural context.1

The technology used, EEG and markerless pose estimation, provides valuable data, but each has inherent limitations. EEG offers high temporal resolution but limited spatial resolution, making it challenging to pinpoint the exact brain regions involved. Markerless pose estimation, while non-invasive, relies on algorithms that can have varying degrees of accuracy in capturing subtle infant movements. Nonetheless, the combined approach offers a comprehensive view.1

This study provides initial insights into how the developing brain gradually transforms music into spontaneous movements of increasing complexity. It establishes that auditory encoding of music is an early developmental achievement, while the motor expression of this perception, particularly in structured patterns, takes longer to mature. The consistent influence of high-pitched music on movement across ages also presents an intriguing area for further exploration. Clinicians working in developmental paediatrics may find the Oxford Handbook of Paediatrics a useful resource for understanding broader developmental milestones.1

> **CLINICAL IMPLICATIONS**
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> The clear dissociation between early auditory processing of music and the later emergence of structured motor responses holds important implications for understanding infant development. Clinicians should recognise

> that while an infant's brain may be actively encoding musical patterns from as early as 3 months, the physical expression of this perception, beyond coarse movements, is a more protracted process. This informs expectations regarding developmental milestones related to music engagement.
> The finding that complex, structured movement patterns only solidify around 12 months suggests that interventions or developmental assessments relying on rhythmic motor responses might be premature in younger infants. Instead, focus should remain on observing general engagement and auditory discrimination in the first half of the postnatal year. The consistent motor response to high-pitched music across all ages also offers a potential avenue for engaging infants, as these frequencies appear to reliably elicit movement.
> For parents and caregivers, this research provides a clearer picture of what to expect. While infants may enjoy music and show basic reactions, expecting coordinated dancing before the first birthday is likely unrealistic. Encouraging exposure to music, particularly high-pitched children's songs, could support both auditory and motor development, even if the movements are not yet perfectly synchronised.

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REFERENCES

1. 1. Nguyen T, Bigand F, Reisner S. Development of auditory and spontaneous movement responses to music over the first postnatal year. Elife. 2026;107088. doi:10.7554/eLife.107088

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